luminescent and radioactive compounds, compounds which have distinct or recognizable light scattering or other optical properties, and compounds which are only detectable upon binding to the characteristic determinant. It should be clear to those skilled in the art that when the target analyte is simultaneously labeled with a magnetic label and a detection label, it is necessary that the binding ligand on the magnetic label recognize a separate epitope on the target analyte from the one recognized by the detection label.

[0305] In a preferred embodiment, more than one target analyte can be sorted by a single processing in the magnetic microchannel. For example, the mixture is treated with magnetic particles conjugated to anti-A which have high magnetic susceptibility and particles conjugated to anti-B which have low magnetic susceptibility. The labeled mixture is then applied to the device and a magnetic field strength sufficient to retain both A and B associated magnetic particles is supplied. In elution, the magnetic field strength or the magnetization of the eluting ferrofluid are altered so as to release particles which are associated with B but not those associated with A, thus effecting a separation of A and B.

[0306] In principle, any number of components in a sample can be labeled with magnetic particles of differing magnetizations by treating various groups of labels with a different specific binding ligand complementary to a chosen component of the mixture. As described above, the labeling can be done in a single labeling reaction, or, more preferably, in separate reactions. Each component will then uniquely react with one representative composition of a particular magnetization. The labeled mixture, when subjected to the magnetic microchannel results in a chromatographic pattern of components separated according to the magnetization of the particles with which they are conjugated. Once processed in the microchannel, the target analytes can then be further processed and/or detected, either together or separately.

[0307] In a preferred embodiment, particles of differing magnetizations are separated by providing a plurality of gradient inducing features. By varying the dimension of each gradient inducing feature, several regions of differing magnetic field strengths are established within the magnetic channel. Magnetic or magnetically-labeled particles are sorted into these areas of differing magnetic field strength according to their particular magnetic response.

[0308] The present invention is applicable for a variety of purposes. For example, the device can be used to isolate and/or detect cells, nucleic acids, or proteins. The target analytes can be enriched and/or purified by being captured to the magnetic microchannel and thus separated from the rest of the sample. Alternatively, the target analytes can be separated from other components that are retained in the channel. Advantageously, the magnetic microchannel in the present invention can easily be washed after each use, so that a single microfluidic device can be reused, either to detect the same kind of target analytes, or a different kind of target analytes.

[0309] In a preferred embodiment, the microfluidic devices of the invention are used to isolate and/or detect a particular kind of cells. Suitable cells are described above. In some embodiments, the presence of a certain kind of cells can be determined for diagnosis or other analytical purposes. In some other embodiments, cells can be isolated so that the target analytes within the cells can be further processed and detected.

[0310] Depending on the particular configuration of the device, target cells are first separated from other components in the cell separation module before they are labeled in a labeling chamber and processed in the magnetic microchannel. However it is also possible to first label the cells in the sample, separate out cells from other components in a cell separation module, and then process the cell mixture in the magnetic microchannel. A cell separation step prior to a labeling reaction allows the enrichment of the target cells in the sample, and thus facilitate the labeling reaction. Similarly, a cell separation step prior to the processing in the magnetic microchannel increases the capturing efficiency of the target cells. On the other hand, the magnetic microchannel itself may serve the purpose of a cell separation module for subsequent processes.

[0311] The labeling of the cells with magnetic labels are outlined above. The magnetic labels contain binding ligands that recognize a specific epitope on the cell surface. The labeled cells can then be captured in the magnetic channel and be separated from the rest of the sample.

[0312] In a preferred embodiment, the target cells are simultaneously labeled with a magnetic label and a detection label, so that they can be directly detected while captured in the magnetic microchannel. The addition of a detection label on the cell can also be carried out within the channel, while the cells are capture, for example using a method similar to the immunostaining technique. Alternatively, the target cells may be detected directly without a detection label. For instance, the target cells may express a GFP and thus can be detected by a fluorescence microscope.

[0313] In a preferred embodiment, the target cell are subjected to a cell lysis reaction while captured in the channel. In this embodiment, lysis buffer are introduced from a buffer inlet port under a condition that a substantial amount of cells can be lysed. The resultant cell lysates can then be collected from a sample outlet port. The cell lysated can be subjected to another round of magnetic labeling and processing in a magnetic microchannel. Alternatively, the lysate can be processed in other modules of the device.

[0314] In a preferred embodiment, cells captured in the magnetic channel are eluted from the channel. When intact cells are to be detected, the cells are eluted by magnetic ferrofluid, reversal of the electromagnets, or a releasing reaction that does not disrupt the integrity of the cell. The eluted cells, further released from the magnetic label if necessary, are then detected. The detection can be achieved by routine methods such as fluorescent microscope, cell counting and sorting devices, etc.

[0315] In a preferred embodiment, the microfluidic devices of the invention are used to detect target nucleic acids. In this embodiment, target nucleic acids are labeled by magnetic labels containing a binding ligand such as a complementary nucleic acid, a nucleic acid binding protein, etc. The labeled nucleic acids are then captured by the microchannel and separated from the rest of the sample.

[0316] Optionally, the target nucleotide in the sample can be amplified by means of in vitro amplification reactions, such as the PCR techniques and other techniques fully